XI. "Description of a Pendulum-Electrograph now in use at the Melbourne Observatory." By R. L. J. Ellery, Government Astronomer to the Colony of Victoria. Communicated by Balfour Stewart, Esq., F.R.S. Received May 23, 1868.

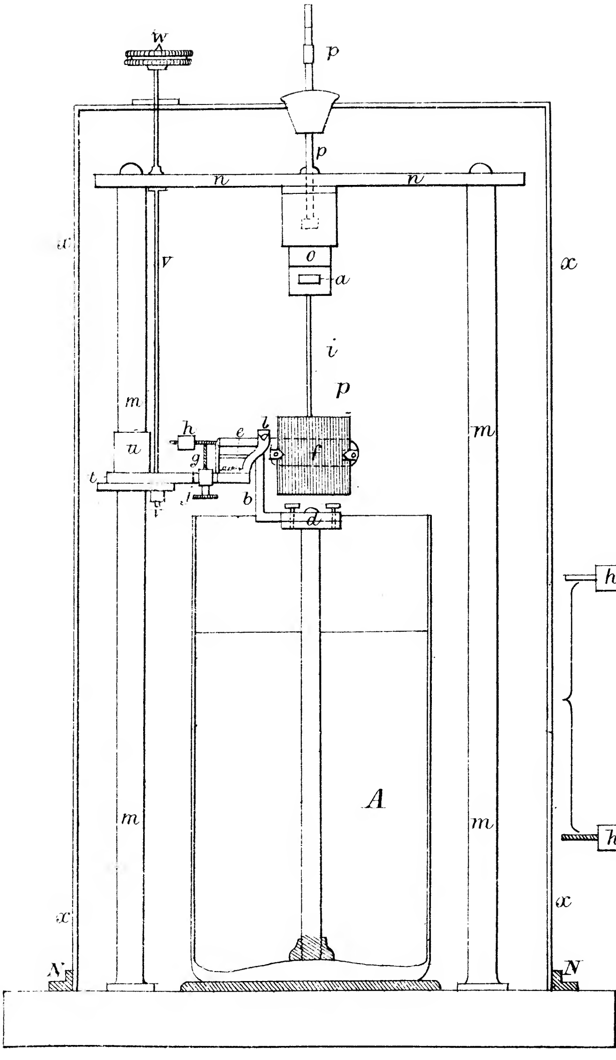
(Plate II.)

About eighteen months since, being desirous of making some improvements in our mode of observing atmospheric electricity, I tried a series of experiments with Sir William Thomson's various methods of obtaining observations and measures of the electric state of the atmosphere; the results of these were so very satisfactory that I had a divided-ring reflecting electrometer made, as nearly similar as possible, judging from the descriptions available, to those used by himself. This was attached to a water-dropping collector, and I obtained the deflections of the needle measured by means of a telescope and reflected scale. Prior to this, all observations of atmospheric electricity were made with Quetelet's modification of the Peltier electrometer, where the needle and its little directing magnet are suspended by a cocoon fibre instead of on a point. The use of this, however, was very troublesome, involving its being carried to the highest part of the building at every observation, brought down, and placed on its stand within doors, the needle brought to rest by a magnet, and, after reading off the force of repulsion, the ascertaining of the character of the electricity by a separate operation. After using the divided-ring electrometer for a few weeks, it became apparent that no method of observing atmospheric electricity that was not continuous could possibly afford results that would embrace the numerous and rapid changes which take place. I found also in observing with the divided-ring electrometer that the torsion of the platinum wire was uncertain, requiring very frequent alteration of the zero-point, especially after great disturbances.

I therefore endeavoured to devise an electrograph that should act by gravity instead of torsion; and for this purpose the electrometers of Sir W. Thomson and the photographic registration method adopted in the Kew magnetographs afforded me a sufficient groundwork. In August last I so far succeeded as to obtain regular photographic curves of the electric condition of the air about 18 feet from the earth's surface; experience of the first temporary apparatus suggested modifications; and in November an improved instrument was erected, of which a brief description was read before the Royal Society of Victoria in December. Some defects in the performance of this, however, led to even a further modification; and since December last the improved electrograph has performed most satisfactorily.

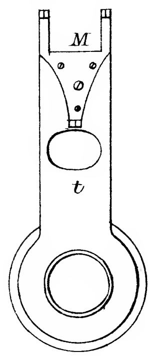
Plate II. will explain its construction. It may be generally described as consisting of—

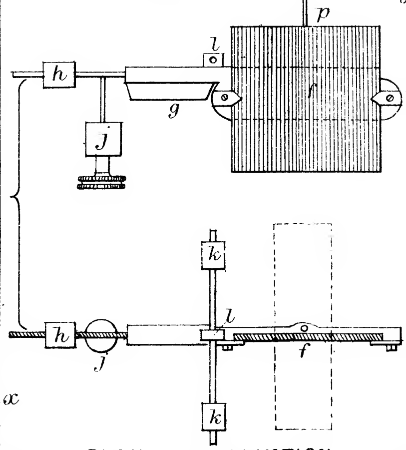
1. Reservoir of electricity.
2. The pendulum.
3. Electrodes.



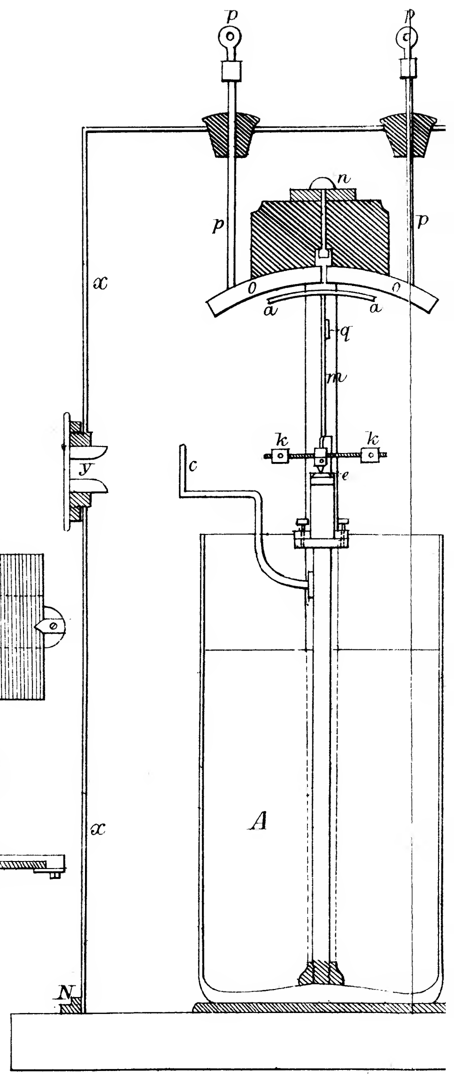
SECTIONAL FRONT ELEVATION

PLAN OF CRADLE.

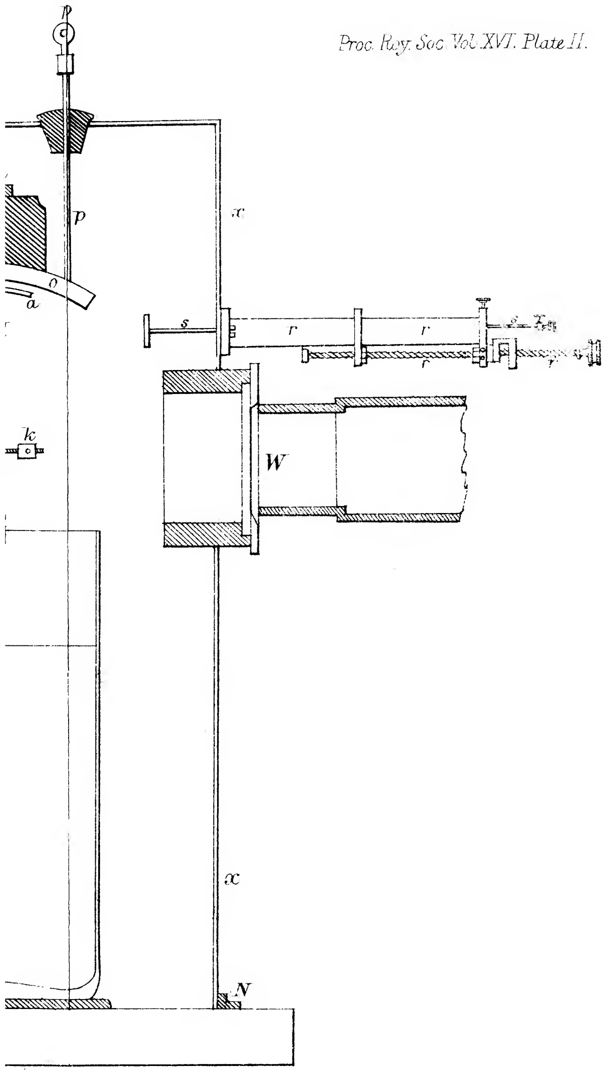




PLAN AND ELEVATION OF PENDULUM.



SECTIONAL SIDE ELEV



E ELEVATION

J. Basire lith.

4. Charge-measurer apparatus.
5. Lifting-cradle.
6. Outer metallic cover.
7. Charging-apparatus.

1. *Reservoir of Electricity.*—On an octagonal slab of slate 1 inch thick and 15 inches from side to side, is fixed an ordinary Leyden jar, A; to the inside bottom of this jar, and in connexion with its inside coating, is fixed a pillar of brass tube reaching to about the level of the mouth of the jar; to the top of this is fixed the support (*b*) for the moveable part with its mirror. Connected with the pillar, and projecting upwards and outwards beyond the top of the jar, is a branch of metal terminating in a ring (*d*), to facilitate charging the Leyden jar.

The support of the moveable part will be best understood by reference to the Plate, where it is marked *d*; it consists of a Z-shaped piece of brass attached to the top of the pillar with a central screw and *three set screws*, by means of which the surface (*e*) upon which the moveable part rests may be set quite level. The surface (*e*) is of polished hardened steel about 1 inch long and $\frac{1}{4}$ inch broad, dovetailed into the brass Z-piece.

2. *The Pendulum.*—The moveable or sensitive part (P), which may be called the pendulum, has its centre of gravity and point of suspension nearly coincident. It consists, first, of a mirror-frame (*f*) and knife-edge (*g*) with counterpoise (*h*), needle (*i*) with its counterpoise (*j*) and balance-screw (*k*). The mirror, a piece of silvered parallel glass about 1 inch square, is clamped on to its frame by two little clips; the knife-edge (*g*) is of hardened steel, and is fixed as nearly as possible in a plane with the silvered surface of the mirror; the counterpoise brings the centre of gravity of the whole nearly to the centre of the knife-edge.

The needle is a piece of No. 16 aluminium wire fixed to the back of the mirror-frame, projecting vertically upwards for about 4 inches from the level of the knife-edge, and terminating in a piece of thin sheet aluminium (*a*) about $1\frac{1}{4}$ inch long and $\frac{1}{2}$ inch wide, bent to a curve of 4 inches radius and fixed to the wire at right angles to the plane of the mirror, and with the chord of its curvature at right angles to the wire itself. The counterpoise to this is found at *j*; a small brass wire, screwed, projects downwards from the frame and carries a small weight, which can be adjusted by screwing up and down the wire so as to obtain the required sensitiveness of the pendulum. The balance-screw (*k*) is a piece of small brass wire screwed its whole length, terminating at each end in a little capstan head. It is attached at right angles to the frame and perpendicular to the plane of the mirror by means of a small stud (*l*), through which it can be screwed in order to adjust the whole pendulum to the required verticality.

3. *Electrodes.*—Firmly fixed to the slate base are two stout pillars of brass (*m, m*), $\frac{3}{4}$-inch diameter and 20 inches high; these are connected at the top by a bridge of stout brass (*n*), to the centre of which a block of ebonite carrying the electrodes (*o, o'*) is firmly screwed. These consist of two seg-

ments of a ring of brass of $4\frac{5}{8}$ inside and about $4\frac{7}{8}$ outside radius, and $\frac{3}{4}$ of an inch wide; they are firmly screwed to the ebonite so as to form together a true arch, but with the end at the vertex separated by about $\frac{1}{16}$ of an inch, care being taken that they are perfectly insulated from one another and from all other parts. Attached to each electrode is a stout brass wire ($p\,p'$) projecting upwards and ending in a ring*.

4. *Charge-measurer.*—On the aluminium stem of the pendulum, and about two-thirds of the distance between the centre of the mirror and the curved piece of aluminium from the former, is a disk of gilded mica (q), $\frac{1}{2}$ an inch in diameter with its plane parallel to that of the mirror; fixed to the outer metal case (to be described) is a sliding-tube and screw (r), through which passes a steel wire (s) terminating inside the case with a disk of sheet brass 1 inch diameter. This is so arranged that the wire disk can be pushed free through the sliding-tube and fixed with the disk at any definite distance from the mica disk; while a further and gradual approach is made with the sliding-tube and screw, both of which are divided; the wire is graduated to inches, the tube and screw together measuring to $\frac{1}{60}$ of an inch. The large disk, when withdrawn, rests against the side of the covering case 6 inches from the needle. The screw is a four-threaded one with six turns to the inch, and is sufficiently long to allow of 2 inches' motion of the sliding-tube.

5. *Lifting-Cradle.*—This consists of a cradle analogous to the lifting apparatus of a good chemical balance. It lifts the pendulum at three points; one is a V, a prolongation of the knife-edge, the other two are formed by the arms of the balance-wire; the cradle (M) is fixed to a piece of ebonite (t) projecting from a tube (u) which slides on one of the pillars, which can be moved up and down to the required extent by a screw ($v\,v$) passing upwards through the bridge. This screw is worked by a key (w) through the top of the outer case. The cradle is set upon the ebonite with adjusting screws, so that it can be made to lift the pendulum quite symmetrically, and lower it without setting it vibrating.

6. *The outer metallic cover.*—$x\,x\,x$ is a cylinder of copper 22 inches high and 12 inches diameter, covered at the top. It has a flange (N) of brass at the bottom which is ground flat and fits almost air-tight on the slate slab; three studs find their places in three holes in the slab and keep it in position. In front of the mirror is the window (W) of the cylinder, which is closed by a piece of parallel plate-glass, and covered outside by a metal plate having two tubular openings, to which are fitted the telescope and dark channel for leading the slit of light to the mirror and thence to the cylinder, as in the case of the Kew magnetographs. At the back and opposite the window is the charging-hole (y); this is an opening lined with ebonite and having a cap to screw on outside. Above the window, the sliding-tube and screw of the charge-measurer ($r\,s$) is fixed. On

* Adopting Sir W. Thomson's plan, I have since covered all the ebonite or vulcanite parts with paraffin with great improvement in insulation.

the top of the cylinder are two tubular apertures lined with plugs of ebonite, through which the external parts of the electrodes pass. The key for lifting the pendulum is also fitted on the top of the case.

7. *The charging-apparatus.*—This consists of an ordinary electrophorus, and of a rod of wire covered with gutta percha or ebonite, terminating at one end in a brass knob, at the other in a projection of uncovered metal for placing in contact with the ring which projects from the Leyden jar pillar.

The air inside the cylinder is kept perfectly dry by two leaden trays, containing lumps of pumice-stone saturated with sulphuric acid*.

The arrangement of light, cylinder for photograph-paper and clockwork, as also of the reading-telescope and scale, are in all respects similar to those adopted for the vertical-force magnetograph of Kew, and described in the Report of the British Association for 1859.

The water-dropping apparatus is of the same kind as described by Sir W. Thomson in Nichol's Cyclopædia (1860, art. "Atmospheric Electricity"). The cistern contains about twenty-eight gallons, which is found to give the requisite stream for about thirty hours. It is a copper vessel, 2 feet square and 1 foot high. Keeping it shallow avoids much alteration of head of water, and consequently secures a more regular stream: this tank rests upon four ebonite insulators indoors. A copper pipe ending in a fine nozzle passes through a hole in the glass of the window, and projects to about four feet beyond the wall of the building; the tank is connected with the electrometer in another chamber by means of a copper wire very thickly covered with gutta percha.

The mode of using the whole apparatus may be thus describod. The Leyden jar or reservoir is first charged by a few good sparks from the electrophorus; to do this the cover of the opening (y) is removed and the charging-rod inserted so that the bare end rests on the ring (c). The sparks from the electrophorus are then passed to the brass knob, which projects a few inches outside the case. The rod is then withdrawn and the opening closed. The act of charging generally sets the pendulum oscillating; it soon comes to rest, however. An hour after charging I have generally found the charge sufficiently permanent for commencing registration. The two electrodes are then connected with the earth; in a minute the reading of the reflected scale will give what may be styled *charge-zero*, which is always different from the *zero-reading before charging* the jar, the latter being the reading of the position of rest of the pendulum (which, by the bye, I make so sensitive as to vibrate about once a second). The charge has now to be measured in terms of the slide and screw. To do this, the wire is first pushed in till the disk is at some definite distance from the pendulum-disk; to admit of this being done precisely and quickly, a

* It is necessary that the sulphuric acid be quite pure, for nitric acid is often an impurity in commercial samples, which soon corrodes all the parts. To avoid this, it is best to heat the sulphuric acid well in a platinum dish and drive off all the nitrous fumes.

small stop (z) is fixed on the rim, and when the stop is home and the screw and slide reading two inches, the disks will be exactly two inches apart. The disk is then gradually approached by means of the screw until, by the attraction exerted upon the pendulum and consequent movement of the mirror, the reading of the scale has altered any definite but small amount (say, $=10'$); the indices of the slide and screw are then noted and entered as the *charge-reading.* The photographic cylinder is now adjusted to its place, and the dot of light falling on it ascertained to be of its proper brightness; for after charging and after great atmospheric disturbances the pendulum will be found to have shifted, slightly displacing the dot laterally, and rendering it weak and undefined; a gentle lifting and lowering of the pendulum, however, by means of the *lifting-apparatus* and screw sets this right immediately.

The air-electrode (p) is now disconnected from the earth, but p' is left connected; the needle then assumes a slightly different position, which after five minutes is read off by the telescope and entered as the *earth-reading.* This position becomes also photographed, and will appear as a short but undisturbed line on the sheet. At the end of the five minutes the wire leading to the water-dropper is attached and the whole left for twenty-four hours; at the expiration of this period the tank is detached, and five minutes after the earth-reading taken and entered as before. The two electrodes are then connected and the charge measured, the light and barrel readjusted for the second day's curve, scale-reading observed and entered again, and so on for the next twenty-four hours.

The curves show at the commencement and end of each day a short straight line already referred to, and corresponding to the mirror's position for the earth-reading; a line drawn from one to the other of these gives the zero or base-line for the day; any loss in the charge of the jar, which is assumed to be proportional to the time, is thus accounted for; for the line will be inclined to the edge of the sheet in proportion to the loss in the twenty-four hours. In the case of this electrometer, the charge of the jar being positive, and the front electrode being the one connected with the air, a positive charge will raise the reflected beam of light, and a negative one lower it; so that the curve above this zero-line indicates positive, and below it negative electricity.

It now remains to show how the indications of the apparatus are reduced. The standard I have adopted is one cell of Daniell's battery. The deflections of the pendulum will be very nearly a joint measure of the charge of the jar and of the electric potential of the air where the water breaks into drops; the charge of the jar, as I have shown, is arbitrarily measured in terms of the screw every day; and the value of these measures, in terms of Daniell's cells, is obtained as follows:—A 12-cell Daniell's battery is placed at hand: the reservoir is first charged pretty highly and left for an hour; the electrodes are then both connected with the earth, and the reading of the reflected scale obtained as a zero. The

charge-measuring disk is now approached to the pendulum-disk until a sufficient deflection is caused to alter the scale-reading (say, 10′) from the zero, and the indication of the slide-tube and screw noted as *charge-reading.* The electrodes are now disconnected from the earth and connected with the 12-cell battery, one with one pole and one with the other, and the deflection then read off; the poles are then reversed and a second reading obtained. The *charge-reading* is now obtained again, as well as the *zero-reading.*

The following actual observations will further elucidate this:—

	Scale-reading.	Screw-reading.
Zero	96·5	
Charge	..	940
Battery P	101·6	
Battery N........	90·4	
Charge	..	940
Zero	96·2	

The reading for battery in first positions differs from zero by +5·1 divisions, and in the second by −5·8 divisions. A deflection of 5·45 divisions is therefore equal to twelve Daniell's cells when the charge-reading is 940. The charge is now reduced and the same process is gone through. This is repeated for eight or ten degrees of charge; and by this means we obtain a set of readings of the amount of deflection caused by a 12-cell battery for various states of the charge, as well as arbitrary measures of the charge by the screw- and slide-tube.

One set of observations gave the following results:—

When the reading of the charge-measurer (with the disks near enough to produce a deflection of 10′) is	Twelve cells Daniell's battery causes a deflection of pendulum of
1·00	0·06 scale-divisions.
2·00	0·76 ,,
3·00	1·39 ,,
4·00	1·90 ,,
5·00	2·35 ,,
6·00	2·80 ,,
7·00	3·32 ,,
8·00	3·96 ,,
9·00	4·80 ,,
10·00	5·89 ,,
11·00	7·30 ,,
12·00	9·09 ,,

The distances between the disks when the charge-measurer reads 1·00 and 12·00 were 1·16 inch and 3 inches respectively. From this a Table is computed, in which the value of the scale-reading and of the ordinates to

the curves in terms of the Daniell's cells is shown for every value of the charge of the reservoir.

This apparatus has scarcely been in use for a sufficiently extended period to allow of any reliable deductions being made as to the existence of laws in the variations of the force of atmospheric electricity, or of any relations that may exist between this and other meteorological phenomena. Some facts, however, can be already gathered from the curves obtained. These are, first, the periods of maxima and minima, which are most distinctly shown. The former occurs at from $6^{h}\ 30^{m}$ to $8^{h}\ 30^{m}$ A.M., the latter at from 1 P.M. to 3 P.M. A second maximum at from 9 to 10 P.M., and a second minimum at from midnight to 2 A.M. are also indicated.

The greatest disturbances take place during our northerly winds, especially in dry hot weather, when a very great negative tension often occurs, so strong as to be beyond the measuring-power of the instrument, in which case sparks may be generally obtained from the air-electrode. The usual turning of the wind from N. to S.W. is always accompanied for a short period by an almost equally high positive tension, but during strong and hot northerly winds the high negative tension lasts as long as the wind blows strong and dry.

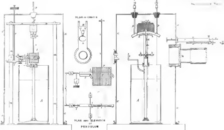
XII. "Further particulars of the Swedish Polar Expedition." In a Letter addressed to the President, by Prof. A. E. Nordenskiöld. Communicated by the President. Received June 12, 1868.

Stockholm, June 7th, 1868.

Sir,—I had last night the honour of receiving your letter, and hasten to express my gratitude for the offer of some magnetical instruments. As an able *élève* of Prof. Edlund, Dr. Lemström, will join the expedition, exclusively for studying the meteorology and terrestrial magnetism of these remote regions, I hope that these instruments will be often and advantageously employed. But *the expedition will start from Gottenburg the 1st July, or from Tromso the 9th July.* The boxes can be addressed to *Count Ehrenward, Gottenburg,* or *Consul Aagaard, Tromso.* Excepting myself and two officers of the Navy (Capt. Baron v. Otter and Lieutenant Palander), the expedition will consist of—

Doctor Malmgren, ,, Smitt, ,, Nyström, Mr. Holmgren,	Zoologists.
Doctor Fries, ,, Bergren,	Botanists.
Doctor Lemström,	"Physiker."

A Geologist, a Conservator, and about 20 Mariners.



SECTIONAL FRONT ELEVATION

SECTIONAL SIDE ELEVATION